Social Innovation in Industry 4.0
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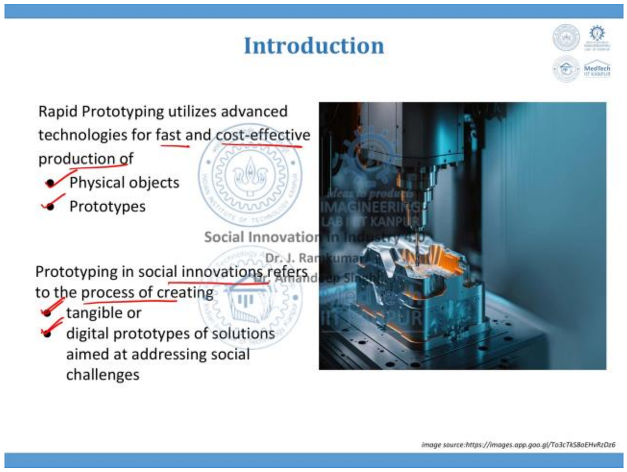
Lecture 38
Rapid Prototyping

Welcome back to the course on Social Innovation in Industry 4.0. We have discussed about Social Innovation to large extent in Industry 4.0. Introduction is also given in the past weeks. In the recent week we casted a glance over the medical devices and agricultural machinery and how Social Innovations are going through or in them also.

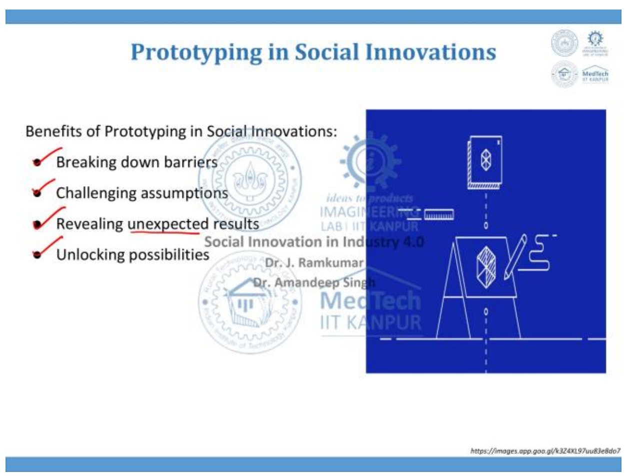
I talked about Rapid Prototyping, a term that is there in which rapidly we try to produce the prototypes. We will see the comparison between prototyping and rapid prototyping in this lecture. And also, we will try to see further the rapid prototyping techniques, technologies which are available. The demonstration or the rapid prototyping machine and on the CAD modeling, that we will be covering in this week.

Rapid prototyping and prototyping, if we compare, we will go through the Content like this. Prototyping in Social Innovation. Why do we even need Prototyping? And, Prototyping Strategies and Approaches, Types of Manufacturing Processes for Prototyping, Steps Involved in Rapid Manufacturing. I would keep using the word Rapid Manufacturing or Rapid Prototyping as in interchangeable terms, though prototyping was only the term when it was used for prototyping. That is the initial field of the product was being developed, that is known as rapid prototyping.

Then, this kind of the rapid prototyping technique is used for the further manufacturing of large number of components, that is also called as Rapid Manufacturing or nowadays, it is also called as Additive Manufacturing. Then, we have Reverse Engineering Utility for Rapid Manufacturing, Rapid Prototyping Applications, Future Trends and Challenges.



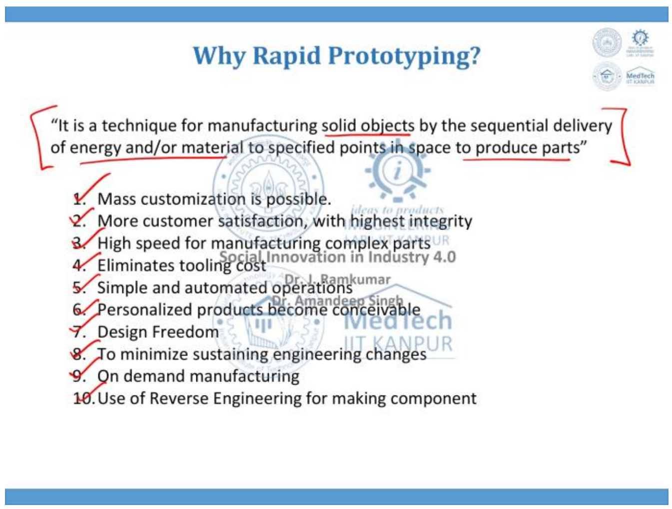
Rapid prototyping utilizes advanced technologies for fast and cost-effective production of physical objects and prototypes. Prototyping in Social Innovations refers to the process of creating tangible or digital prototypes of solutions aimed at addressing social challenges.



Benefits of having rapid prototyping could be many. It helps us to break down the barriers. That means, through tangible and visual representation we are able to have a feel of the product, the barriers on how the product would look like, are covered here.

Assumptions whichever were made are challenged here because we have iterative testing, and based upon the feel of the product in hand that we have, we can also give a feedback. So, assumptions are challenged and could be updated. In revealing unexpected results, for the informed development expects which are sometimes not expected in the just feel kind of a phase.

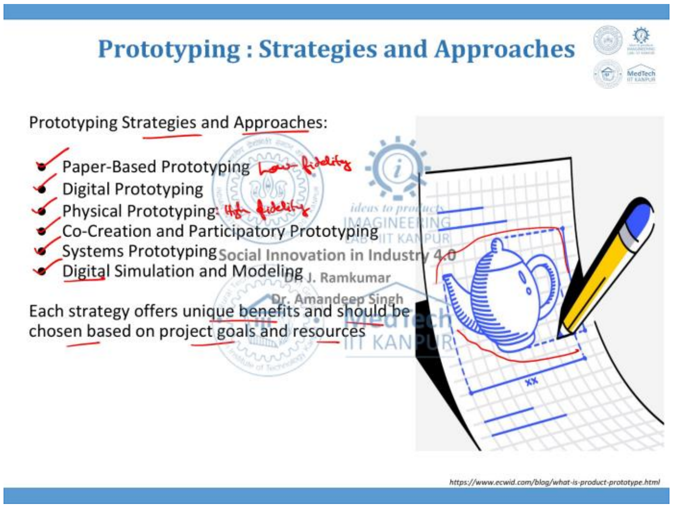
When we try to have the prototype in front of us, the unexpected results also do come. Unlocking possibilities, that is for fostering creativity and innovation, further possibilities are unlocked when we try to prototype Social Innovations.



Why Rapid Prototyping? Rapid prototyping is a technique for manufacturing of solid objects by the sequential delivery of energy or material to specified points in space to produce parts. A well-defined statement to say what rapid prototyping is the technologies could be any. We can even change the material, or we can even change the energy level to produce the objects, which are in the physical form, this is what rapid prototyping is.

So, here certain benefits are there which we will see in the next lecture in detail. Mass customization is possible, that is more and more customer could come. More customer satisfaction is there because highest integrity is there, and it is faster process that is high speed for manufacturing of complex parts. It eliminates tooling, it is a simple and automated operations, personalized products become conceivable, design freedom is there. We will see at the end of the slides, why design freedom is better in rapid prototyping? To minimize sustaining and generating changes.

And, on demand manufacturing that is customization is again possible   and use of reverse engineering for making components are a few of the benefits of rapid prototyping which makes it a technique, which is unavoidable when we are talking about Social Innovations.

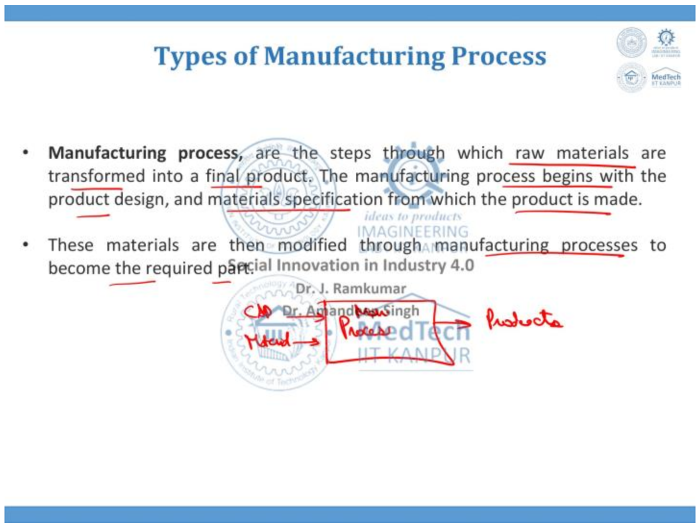


Prototyping Strategies and Approaches. Prototyping could be paper-based. There is a fidelity or strength of the prototypes that we are trying to develop. It could be low fidelity, it could be high fidelity in between we can have various levels of medium fidelity.

High fidelity prototype is that is a kind of a almost complete functional prototype. For instance, if it is a prototype of pen, it should be the fully shape of the pen, and pen should also be able to show what would be the weight or so. If it is just a low fidelity prototype, you can just make a pen out of a paper or out of a cardboard. So, paper-based prototypes that is on the paper only we try to draw something and we try to produce a prototype. On that that is a low fidelity prototype, that is low fidelity sketches or cutouts for quick ideation and collaboration these are used.

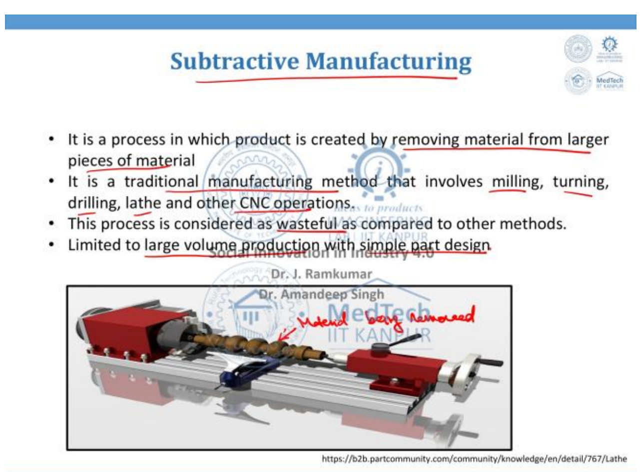
Then, this paper-based prototypes could be converted into digital prototypes as well, with the help of interactive software tools for realistic simulations and for user testing. Physical prototypes are produced for building up the models to test functionality and aesthetics say the fidelity is going high. This is high fidelity, this is low fidelity. Physical prototyping may vary from low to medium to high fidelity any. Then co-creation and participatory prototyping which means involving all the stakeholders in the process of inclusive solutions.

Systems prototyping that is examining the interactions and unintended consequences within the complex systems what will the overall manufacturing system, the vendor development, the manufacturing facility, everything could be prototyped. Digital simulation and modeling, digital simulations means computer-based simulations for a scenario analysis, for a sensitivity analysis, for forecasting, all those could happen in the prototypes, that are digital. Each strategy offers unique benefits and should be chosen based on project goals and resources.



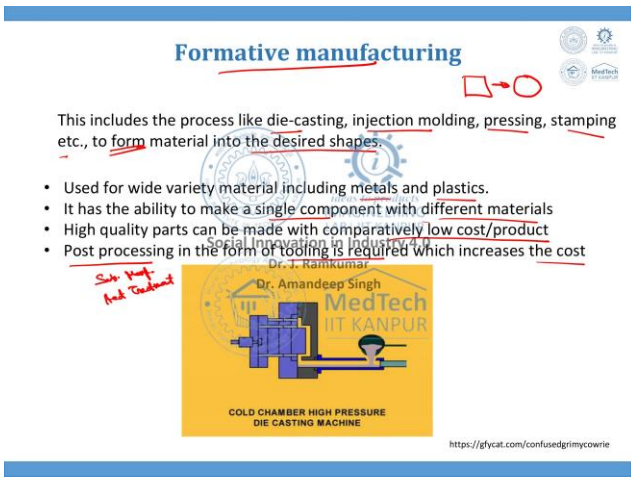
Then, Types of Manufacturing Processes, manufacturing process as a definition are the steps through which raw materials are transformed into final product. The manufacturing process begins with the product design, and material specification from which the product is made.

These materials are then modified through manufacturing processes to become the required part. We have a process that is known as manufacturing process, the input is, maybe the CAD model or the material that gives us the products. There are certain kinds of manufacturing processes.



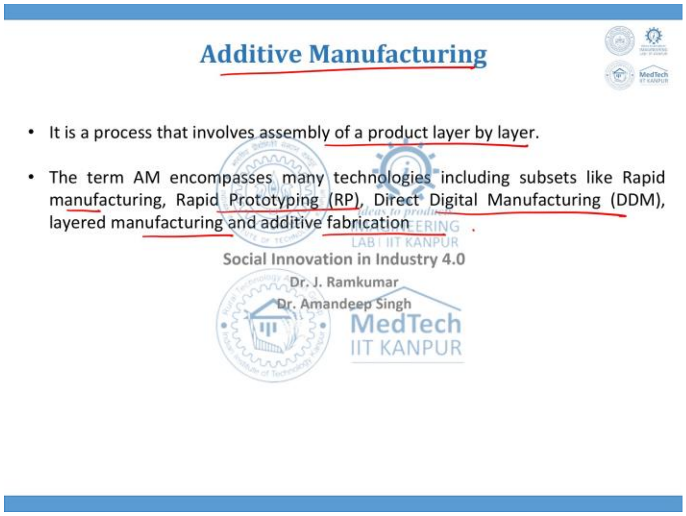
Subtractive Manufacturing is a common manufacturing term, whenever we talk about CNC machining or so that is subtractive manufacturing, because you can see here the material is being removed here. It is the process in which product is created by removing material from larger pieces of material.

It is a traditional manufacturing method that involves milling, turning, drilling, lathe and other CNC operations. This process is considered as wasteful as compared to other methods because a lot of scrap is produced, so it is a wasteful process. It is limited to large volume production with simple part design. So, this is Subtractive Manufacturing.



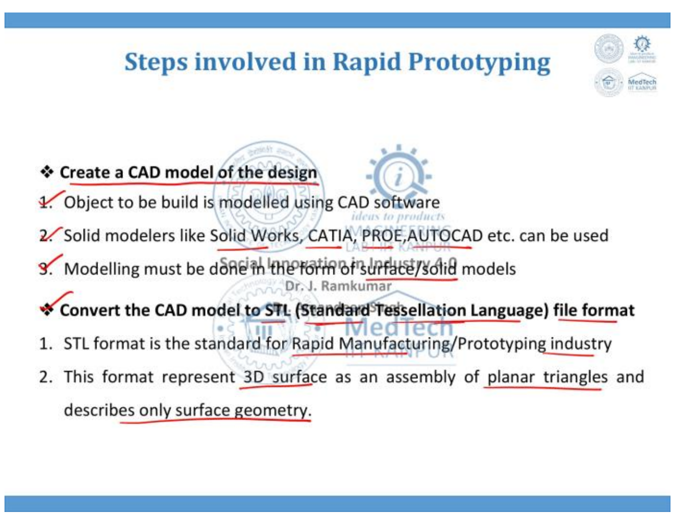
Next comes is Formative Manufacturing. When you are trying to change the form of the material maybe from this to something this. Only form is changed from a cube to a sphere, or so. This includes the process like die-casting, injection molding, pressing, stamping etc. to form materials into the desired shapes. The word is form material, that is transform the material shape.

It is used for wide variety of material including metals and plastics. It has the ability to make a single component with different materials. High quality parts can be made with comparatively low cost here. Post processing in the form of tooling is required which increases the cost that is this. Post processing is again our subtractive manufacturing only, that is the post processing process here. It could be even heat treatment. This is Formative Manufacturing.



Let us now come to the term Additive Manufacturing which is the focus of this week. It is a process that involves assembly of a product layer by layer. The word assembly is there, it is either assembly, it is building, it is making, it is developing, whatever you use here.

The term Additive Manufacturing encompasses many technologies including subsets like Rapid Manufacturing, Rapid Prototyping, Direct Digital Manufacturing, layered manufacturing and additive fabrications. It could be subsets, if I call Rapid Manufacturing and Rapid Prototyping as separate processes. It could be maybe the namesakes, so that Additive Manufacturing itself also called as Rapid Manufacturing or Rapid Prototyping, or so.

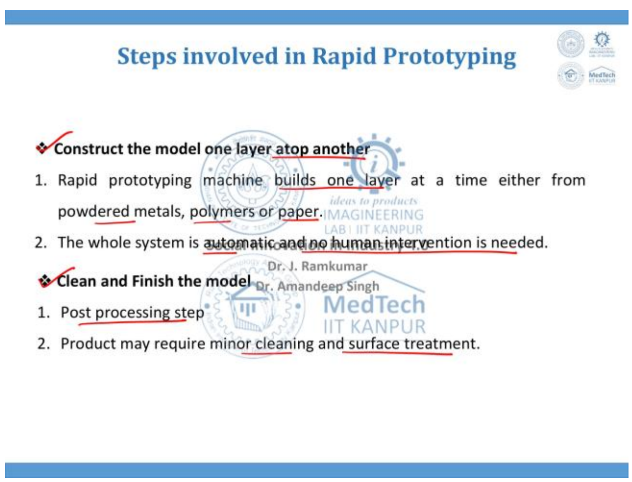


The steps involved in Additive Manufacturing or Rapid Prototyping or Rapid Manufacturing are first is to create a CAD model of the design. Object to be build is modelled using CAD software.

Solid modelers like Solid Works, CATIA, PROE, AUTOCAD etc. can be used. Modelling must be done in the form of surface or solid models in general. So wire frame models are also there. The kinds of models that are required for the specific application.

They are made accordingly in the CAD software, and they are converted into the physical form using the Rapid Prototyping technologies, or we call it as printers. Then, we convert the CAD model to STL file. STL is Standard Tessellation Language which gives us the layer by layer CAD model of the body that is to be manufactured. STL format is a standard for Rapid Manufacturing or Prototyping Industry. This format represents 3D surface as an assembly of planar, triangles and describes only surface geometry.

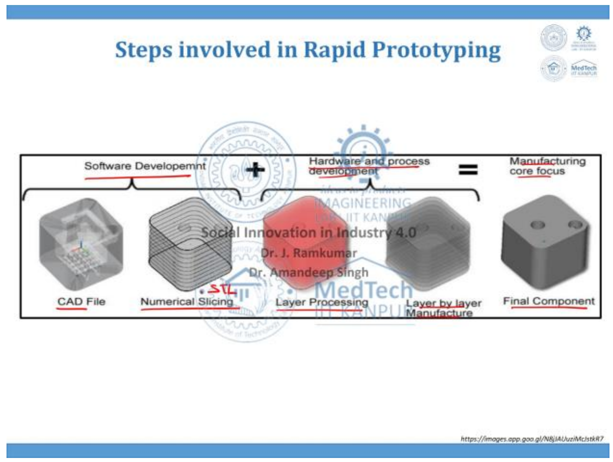
So, STL model is majorly used for only 3D printing. The simulation part is not majorly covered using the STL. If I need to do certain solid simulation or thermal simulation, then STL is not used.



Next step is construct the model one layer atop another which means Rapid Prototyping machine builds one layer at a time either from powdered metals, polymers or paper. We will talk about the kind of the materials which goes as an input to the Rapid Prototyping.

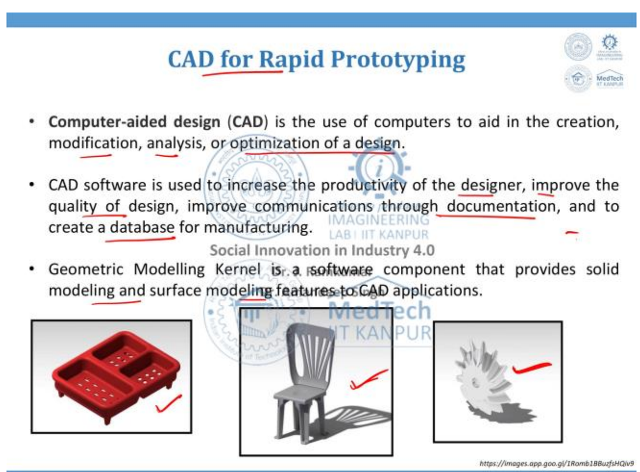
This also becomes a classification of Rapid Prototyping technologies. The whole system is automatic and no human interaction is needed. Human is only needed to load the materials properly on the machine, whether it is a powder or liquid or solid and also to enter the CAD file. Clean and finish the model.

That is the next step. That is post processing step, which could be again subtractive heat treatment, or so. Product may require minor cleaning and surface treatment as well.



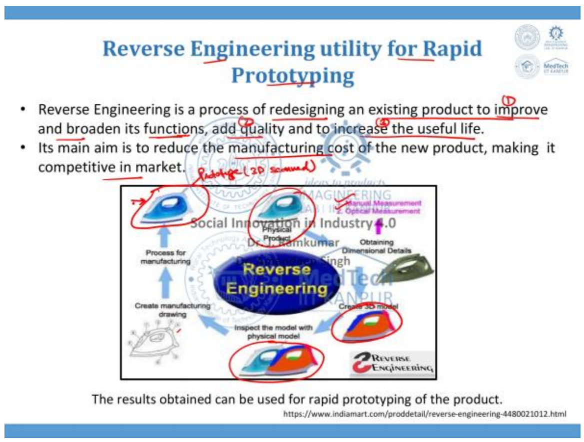
So, these are the steps. We have a CAD file, and we have numerical slicing over it, and we have obtained STL file here.

This is software development only. Then, we have hardware and process development that means we have layer processing using any of the technologies layer by layer. manufacturing of the component. Then, we have manufacturing core focus that if we get the final component, where some heat treatment or some machining might be required to have the desired surface finish and surface properties or maybe also material core properties.



First step CAD for Rapid Prototyping. CAD is a use of computers to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communication through documentation, and to create a database for manufacturing.

Geometric modeling kernel is a software component that provides solid modeling and surface modeling feature to CAD applications. These are all CAD models that you could see. It is just a soap case, this is a plastic chair and this is a gear.



Reverse Engineering as a Utility for Rapid Prototyping, that means even if you do not have a CAD model, you have something in hand, you can scan it using 3D scanners.

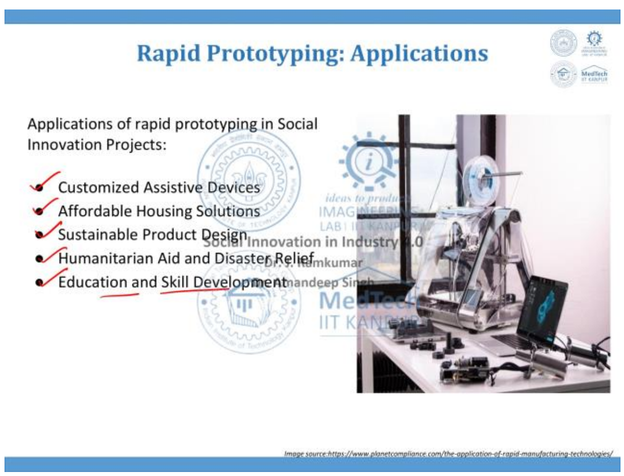
3D scanner would build-up a CAD model for you, and you can try to have a rapid prototype model that is a 3D printed model out of that. So, Reverse Engineering is the process of redesigning an existing product to improve and broaden in functions, add quality to increase the useful life. This is the definition of Reverse Engineering. You can see in the definition 3 major terms are given that is improve and broaden functions, add quality and increase the useful life.

And, the term I just mentioned or the word I just mentioned that we can recreate the function, we can reproduce something that is not mentioned here, because there could be the IPR intellectual property or patent infringements in that.

So, that is why in the definition of Reverse Engineering, it is not said that it is reproducing or redoing it. But yes, to understand the product what a competitors product is there, or what a product is there in a country who has developed a product in maybe 10 times more cost, in which I am targeting to do, I am trying to produce something in 1000, that is available in 10,000 at some other place to reproduce that I can 3D scan it, and try to have a better functions over it. So, that also is one of the use of Reverse Engineering. Its main aim is to reduce the manufacturing cost of the new product, making it competitive in market. The results obtained in the Rapid Prototyping of the product, you can see we have this physical product here.

This physical product we are only trying to having dimensions that in manual measures or optical measures could happen in manual measure or optical measurements could be doing using the simple tools. For instance, if I need to recreate the table that I am using, the table dimensions could be measured using an inch tape, and we can also draw it on a paper, then that paper can be coordinated to CAD, we can try to reproduce that with the table, that is also Reverse Engineering.

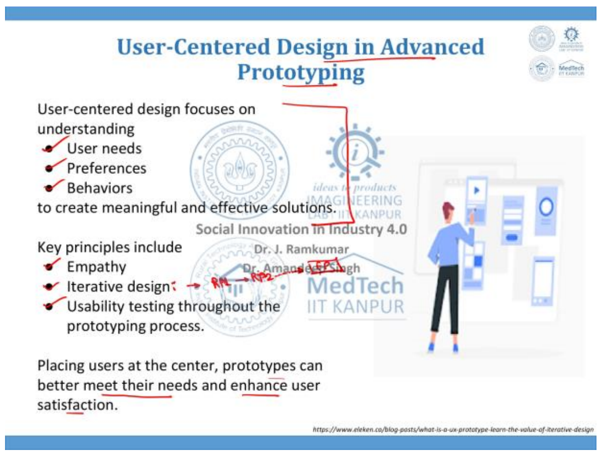
If the shape is little complex, for example, shape of the stylus is little complex, there is a button here, we can scan it using the digital scanners, that is the 3D scanners, which are available. And, we can obtain a CAD model, 3D CAD model and we can also compare the model to the physical model that is actual model, that is scanned and try to have the manufacturing drying out of it, and we have also now produced the final prototype of it, prototype that is 3D scanned. Next comes



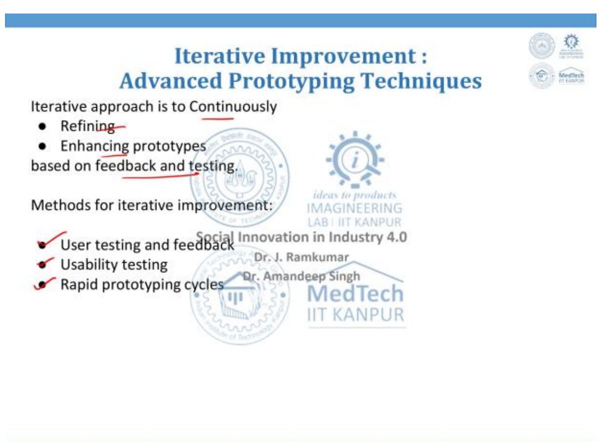
Applications of Rapid Prototyping in Social Innovation projects. There are certain and multiple applications, customized assistive devices. Assistive devices, such as orthotics or many other assistive devices are manufactured using Rapid Prototyping Techniques.

Then, we have affordable housing solutions, that is 3D printed walls or modular constructions in a room, that is their. Sustainable product design, that is we reduce the material waste, and energy consumption and product development cycle is also minimized here, so energy is also saved in that, so sustainable product design is there. Then, humanitarian aid and disaster relief, in medical equipment or temporary shelter in the case of crisis situation, in the construction industry is also sometimes 3D printed.

Education and skill development that is to enhance the hands on learning experiences and to promote innovation in educational settings, we can see, nowadays, almost all the engineering colleges have 3D printers with them. The 3D printers could be as low as of the cost of maybe rupees 6000, or so, nowadays. It can go up to 6 crores or so depending upon the size, complexity and resolution that we are asking for, but for maybe personal use, or for a small institute itself for their use, educational skill development only. 3D printers are also available in low cost to understand the system.

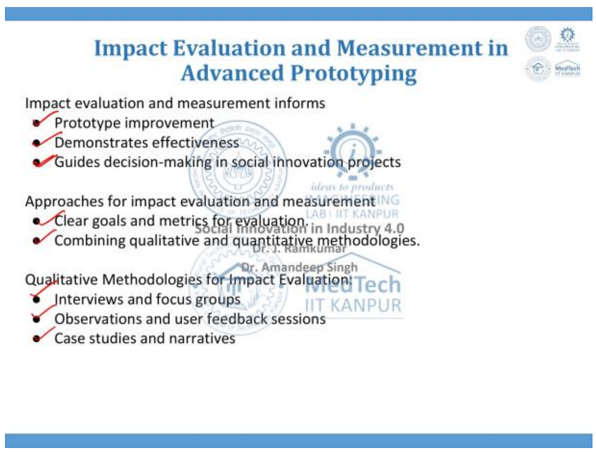


User-Centered Design in Advanced Prototyping. User-centered design focuses on understanding user needs, preferences and behaviors to create meaningful and effective solutions, that is why there is a need of Rapid Prototyping. Here also, the key principles which were discussed earlier are empathy, iterative design, usability testing throughout the prototyping process because design is iterative, you might have to have rapid prototype one, rapid prototype two, and so on, unless we get the final functional prototype. So, placing users at center, prototypes can be better and they meet their needs and enhance user satisfaction.



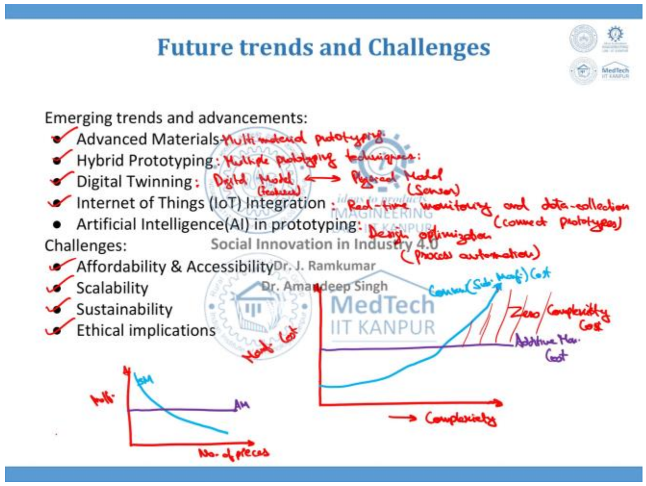
Further iterative approach is to continuously refine and enhance prototypes based upon feedback and testing. Methods of iterative improvement could be user testing and feedback where that is gathering insights from end users to identify areas for improvement.

It could be usability testing that is assessing the usability and effectiveness of prototypes through user interactions, then Rapid Prototyping cycles. And, implementing quick iterations to address design, flaws, and enhance functionalities there.



Next comes Impact Evaluation and Measurement in Advanced Prototyping. Impact evaluation and measurement means we get the information on prototype improvement, demonstrates effectiveness, and it guides decision-making in Social Innovation projects.

Approach for impact evaluation and measurement is clear goals and metrics for evaluation, combining qualitative and quantitative methodologies. Qualitative methodologies for impact evaluation, observation and user feedback session, case studies and narratives.



There are certain Future Trends and Challenges in Rapid Prototyping. For instance, advanced materials have now come. Prototyping that we are doing nowadays is also called as multi material prototyping. That is, when I will talk about the materials of prototyping in the next lecture, there are ranges of material.

And, different kinds of material could also be used to have a multi material prototyping. So, this is the advanced trend in the prototyping. Then, we have hybrid prototyping, which is integration of multiple prototyping techniques. That is, it could be any of the prototyping techniques such as Subtractive, Formatting or Additive. For instance, we can first have something from formative, then we can do small machining over it, that is subtractive happens.

Separately, a different component that goes as an assembly to this part of the prototype, that could be Additive Manufacturing that means hybrid prototyping is always a part of it. Digital twinning, digital twinning is utilizing digital models to simulate and optimize prototypes before physical production. That means we get a digital model which is similar to the physical model.

So, whatever happens to our physical model the same would be reflected in the digital model, and sensors are put here in the physical model, so that any change in heat, in physical condition, that happens to the physical model it is also shown in the digital model at its features. Internet of things integration against internet of things, when I say I am talking about the sensors, these sensors are connected to prototype to have real-time monitoring and data collection.

I will call it as real-time monitoring and data collection. Also, we can connect certain prototypes. Then, artificial intelligence prototyping, this was also discussed in the previous lectures as well. For design optimization, for process automation, artificial intelligence is used or I would put it as process automation. Certain challenges are affordability and accessibility, scalability of the prototype in the size and the shape that we require. Sustainability that is minimizing the energy in that, then ethical implications that is data privacy, intellectual property, potential social implications of Rapid Manufacturing are there, which are to be taken care properly.

So, these are the few challenges that are there in Rapid Prototyping, but still Rapid Prototyping techniques are quite helpful, because the effectiveness that we get through rapid prototyping, if I draw a small graph here, we can see if the product complexity or geometric complexity goes in this direction. Complexity means a simple cylinder is a simple product, the cylinder with varying diameters is a more complex product, with further feature is further more complex product.

So, complexity if it is going in this direction and if I am talking about the manufacturing cost, I will put at manufacturing cost of a product, then generally what happens conventional cost arises like this, that is as and when the complexity is increasing the Conventional Manufacturing Cost. Conventional when I say, I am talking about Subtractive Manufacturing Cost that is rising in this direction.

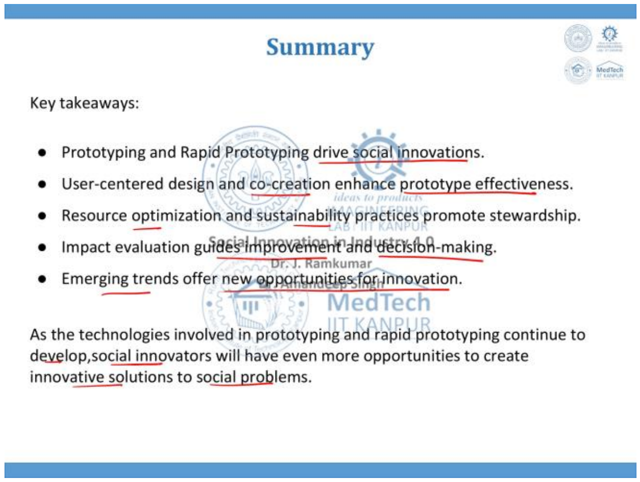
However, Additive Manufacturing Cost is almost the same for any of the complex products, because it is only the CAD design, that is taking time Rapid Prototyping or Additive Manufacturing has to happen layer by layer.

The cost of the products remains for a single number or for 1000 PCs. In Conventional Manufacturing or Subtractive Manufacturing, if one piece is to be manufactured, still we need to have a tooling for that, tooling cost is very high. if suppose, we need to have 10 PCs of the component still tooling is required, if we require 10,000 PCs, then also tooling is required.

So, this tooling cost is distributed into 10,000 if the number of PCs are high, but if complexity is high tooling is also expensive. though the cost in Conventional Machine or Subtractive Manufacturing keeps on rising, but here in Additive Manufacturing the cost remains same, this is Additive Manufacturing cost which means we are having in this area zero complexity cost.

This is the major benefit of Rapid Prototyping or Additive Manufacturing. The lot size, which I just mentioned. If there are high number of PCs or large number of PCs, if I say number of PCs here, and this is the gain, the manufacturing cost, putting the same colors to the lines. For manufacturing a large number of PCs the Subtractive Cost is reducing, but for this Additive Manufacturing, kind of the process the cost almost remains same.

This is Additive Manufacturing, and the other one is Subtractive Manufacturing.



To Summarize this lecture, Prototyping and Rapid Prototyping drive Social Innovations. User-centered design and co-creation enhance prototype effectiveness. Resource optimization and sustainability practices promotes stewardship. Impact evaluation guides improvement and decision-making.

Emerging trends of new opportunities for innovation. As the technologies involved in Prototyping and Rapid Prototyping continue to develop, social innovators will have even more opportunities to create innovative solutions to social problems. I would like to talk about the Rapid Prototyping Technologies in the next lecture, and the next for the two lectures would be the demonstration of that. Thank you.